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CTS Load Carriage System Phase III D -Stage 1: Biomechanical Evaluation Tactical Assault Vest with Wide Webbing Shoulder

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by

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Abstract

The padded shoulder of the M35 TAV (prototype load carriage vest) is to be replaced with three inch wide flat webbing to provide a lower profile and improve compatibility with the padded shoulder strap of the CTS rucksack. A biomechanical comparison of these two shoulder designs was performed to ensure that this change will result in a net improvement in the TAV design.

The Load Carriage Simulator was used to compare the two shoulder designs. It consists of a representative 50 percentile male torso, anthropometrically weighted and covered in an artificial skin analogue mounted on a programmable displacement table. During simulated running, (10 km/hr), both TAV designs were loaded with 141 N and the contact pressure distributions were measured with a Tekscan® FScan system at four locations: left anterior shoulder, left posterior shoulder, left axilla and left hip. In a second test, the two shoulder designs were assessed for pressure distribution and physical compatibility when worn under a loaded (231 N) CTS Rucksack.

The webbed shoulder design performed as well as a padded shoulder did in distributing the load onto the upper shoulder region. A flat webbing design also provided a flatter profile under the shoulder strap of the CTS rucksack.

In both shoulder designs, contact pressures in excess of 35 kPa were caused by the shoulder epaulettes and seams of the combat shirt. These values are sufficiently high to lead to user discomfort in extended wear situations.

Testing also revealed that the inside bottom corner of the metal clips that hold the 1 inch webbing above the C7 pockets caused a point pressure of approximately 30 kPa, even without a rucksack on. This is a potential problem, particularly should loads in the TAV increase.

In general, the design of the TAV should attempt to minimize discontinuities, particularly in the loaded areas of the shoulder. Additionally, the position of epaulets and the shoulder seams of the combat shirt created some of the most problematic pressures. The presence of epaulets and heavy seams will continue to be an issue regardless of the shoulder design of the TAV.

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1.0 Introduction

The major crown project L2646 "Clothe the Soldier" is intended to acquire improved personal protective equipment for Canadian Forces soldiers. In support of this program, the Defence and Civil Institute of Environmental Medicine (D.C.I.E.M.) is supporting the development of an improved tactical assault vest using the knowledge gained and the biomechanical evaluation tools developed under the APLSC R&D programme. [1,2,3]

The padded shoulder of the M35 TAV (prototype load carriage vest) has been replaced with wide flat webbing to provide a lower profile and improve compatibility with the padded shoulder strap of the CTS rucksack. Pacific Safety Products Inc. is responsible for the design and development of this vest under contract #W8476-7-AZ06/001/PR. Testing was undertaken to assess the impact of this change on the pressure loads experienced by the shoulder.

The objective of this work is to assess the pressure distribution of the flat webbing shoulder design and compare it to the previous padded shoulder design. As well, this shoulder design will also be assessed for compatibility with the proposed CTS Rucksack.

2.0 Methods

2.1 Load Carriage Simulator

The Load Carriage Simulator (LC Sim) and the standard test protocols have been reported previously. [1,2,3] It consists of a representative 50 percentile male torso, anthropometrically weighted and covered in an artificial skin analogue mounted on a programmable displacement table. A six degree of freedom load cell is located at the base of the torso which allows the calculation of hip joint reaction forces. Payload location and descriptions are summarized in Table 1.
Contact pressure distribution is measured using a Tekscan® FScan system, using the 9810 sensor. These thin sensors (<0.2 mm) cause minimal disruption of the contact surfaces. They have a spatial resolution of 12.7 mm and contain 96 active sensing areas covering approximately 76 x 200 mm.
Four sites were monitored for their contact pressures. Sensor locations included:

1. Left anterior shoulder
2. Left posterior shoulder
3. Left Axilla
4. Left Hip, including the iliac crest

In order to approximate field use conditions of a TAV; the displacement function frequency of the standard LC Sim test [1,2,3] was modified from 1.8 Hz (walking pace) to 3 Hz (jogging pace).

The LC Sim test sequence was:

i. TAV with padded shoulder alone,
ii. TAV with padded shoulder with CTS Rucksack, rucksack load: 258.3N (58 lbs.).
iii. TAV with webbing shoulder alone,
iv. TAV with webbing shoulder with CTS Rucksack, rucksack load: 258.3N (58 lbs.).

The TAV was loaded with a representative fighting load of dummy kit items, consisting of the items listed in Table 1. It was fitted on the 50 percentile male manikin torso. The manikin was clothed in a CF combat shirt. Figure 1 shows the location of pockets and kit items in the TAV.

Table 1. Fighting load definition and location

Quantity	Item	Location on TAV	Mass (kg)
1	C9 drum	1. right hand side (rhs) above hip	2.80
2	C7 magazines	2. upper chest - medial	0.95
2	C7 magazines	3. upper chest - lateral	0.95
1	Water canteen	4. left hand side (lhs) above hip	1.00
2	Smoke grenades	5. front of C9 pocket and water canteen	0.95
2	Frag. grenades	6. auxiliary pockets	0.95
4	Miscellaneous	6 & 7 auxiliary pockets	4.54
1	TAV empty	-	2.24
		Total Mass	14.38 kg
		Total Load	141.1 N (30 lbs)

The LC Sim was programmed to displace the TAV and person to simulate running over level terrain at 167 metres/minute (10 km/h). As tested, TAV fighting load was 141 N, and total marching load was 400 N (88 lbs.).

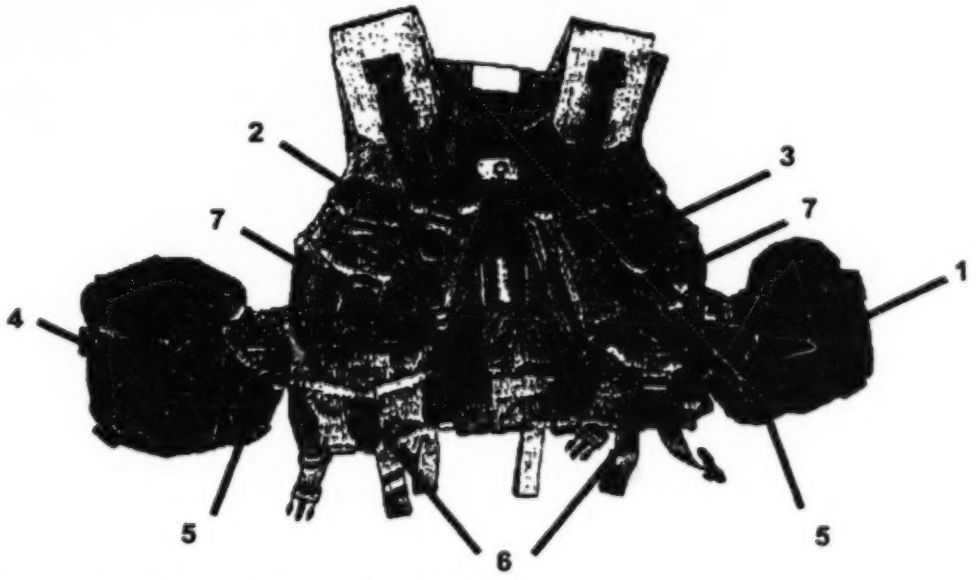

Figure 1. Location of TAV pockets and kit items.

3.0 Load Carriage Simulator Results

3.1 Skin Contact Pressures

Table 4 is a summary of the location and values of the average and peak contact pressures recorded during a simulation of running at 167 m/minute (10 km/h). Previous studies [3,4] have shown that skin contact pressures of > 16 kPa can cause the complete cessation of blood flow to underlying tissue. Tissue damage often begins subcutaneously when underlying bony structures cause crushing of the loaded deep muscle, [5]. In certain circumstances, much higher distributed pressures (up to 120 kPa) can be endured passively for up to several hours without necessarily causing gross tissue damage [5] but the reduced ability to oxygenate this tissue will severely limit the ability of the tissue to do work. Previously, pressures > 35 kPa recorded on the LC Sim have been indicative of user reported discomfort [1].

Table 2. Average and peak contact pressures.
Reported values have an estimated error of +/- 5 kPa. Shaded values indicate peak pressures > 35 kPa.

a) Padded Shoulder TAV

Location	Avg. P (kPa)	Avg. P. with Ruck (kPa)	Peak P. (kPa)	Peak P. with Ruck (kPa)	Cause
Front Shoulder	16.0	19.3	**37**	**51.4**	Epaulette on combat shirt
Back Shoulder	11.9	11.0	22.5	22.5	Taped edge of back panel mesh sits under the padded ruck strap.
Axilla	10.6	17.7	19	**44.1**	Sternum strap attachment on ruck coincides with end of TAV padding

b) Webbed Shoulder TAV

Location	Avg. P (kPa)	Avg. P. with Ruck (kPa)	Peak P. (kPa)	Peak P. with Ruck (kPa)	Cause
Front Shoulder	16.0	15.5	**41.1**	**36.0**	Shoulder seam of combat shirt
Back Shoulder	10.9	12.0	20.3	30.0	Posterior edge of loop Velcro®
Axilla	9.5	20.5	27.0	29.0	Medial edge of metal clip on 1 inch webbing above C7 pockets.

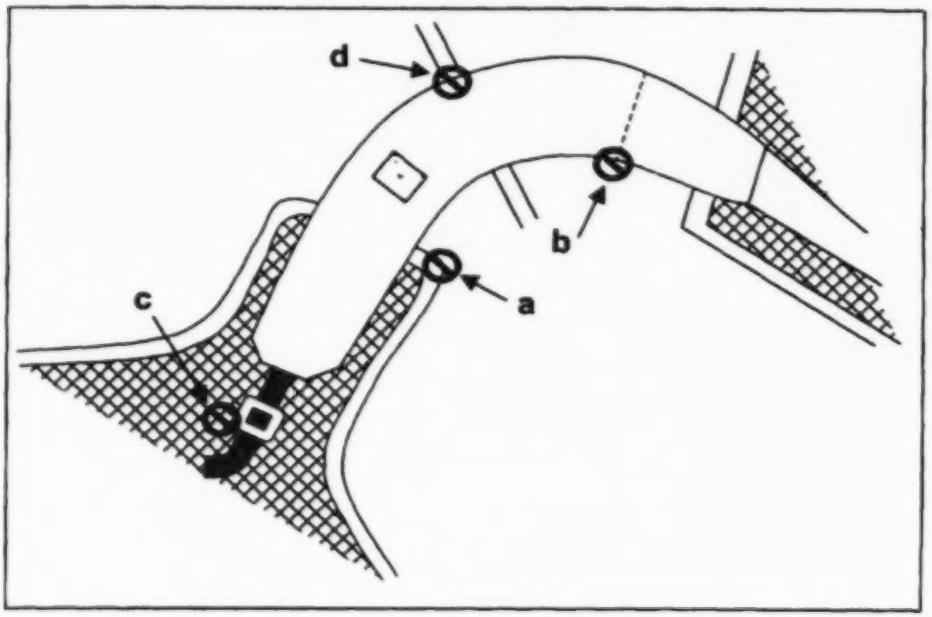

Figure 2 Location and Cause of Pressure Points

a) Discontinuity due to the lap joint, most noticeable at the lateral aspect of the front mesh panel (moderate pressure).
b) End of the Velcro (loop) layer (moderate pressure).
c) Medial corner of the metal buckle levering into body. Pressures approximately 30 kPa with TAV alone. This is a potential source of user discomfort.
d) Shoulder seam of combat shirt, pressures > 35 kPa. This will be a source of user discomfort in extended wear situations.

3.2 Compatibility with CTS Rucksack

The webbing shoulder and padded shoulder designs of the TAV were tested with the CTS rucksack to simulate anticipated field usage and to identify conflicts between the TAV and Rucksack. Neither shoulder design caused conflicts in the shoulder region. As there is a finite surface area available on the torso, some conflicts did occur.

On both TAV designs, there is a space conflict between the bottom of the rucksack shoulder strap and the C9 pocket. This could be addressed in two ways:

1. The C9 drum could be removed from the TAV pocket and placed in one of the outer clam pockets on the rucksack, or
2. the most posterior of the Fastex® clips on the C9 pocket could be released which may allow the rucksack shoulder strap to pass behind the C9 drum.

The rucksack belt is incompatible with the C9 drum on both designs of the TAV. For general fit, the TAV could be temporarily loosened at the shoulders which will allow the "belly" of the TAV to be lifted up and over the rucksack waistbelt.

4.0 Conclusions and Recommendations

1. The webbed shoulder design distributes the load equally as well as the padded shoulder design and provides a flatter profile under the shoulder strap of the CTS rucksack.

2. One corner (the medial aspect) of the metal clip that holds the 1 inch webbing immediately above the C7 pockets causes a point pressure loading of approximately 30 kPa with the TAV alone. This is a potential problem, particularly should the load in the TAV increase.

3. All the load is carried on the shoulders with a vest design. With loads of 140 N and above, some constriction of breathing may be experienced by users. Conditioning will minimize this effect.

4. Contact pressures in excess of 35 kPa were caused by the shoulder epaulettes and seams of the combat shirt. These values are sufficiently high to lead to user discomfort in extended wear situations.

5. The Fastex® buckle on the bottom of the C9 drum pocket caused a point loading of the hip region (>45 kPa). This will result in user discomfort.

In general, the design of the TAV should attempt to minimize discontinuities, particularly in the loaded areas of the shoulder. Additionally, the position of epaulets and the shoulder seams of the combat shirt created some of the most problematic pressures. The presence of epaulets and heavy seams will continue to be an issue regardless of the shoulder design of the TAV.

5.0 References

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